Wrong-site surgery (WSS) is a rare occurrence that can have devastating consequences for patient care. There are several factors inherent to spine surgery that increase the risk of WSS compared with other types of surgery. Not only can a surgeon potentially operate on the wrong side of the spine or the wrong level, but there are unique issues related to spinal localization that can be challenging for even the most experienced clinicians. The following review discusses important issues that can help prevent WSS during spinal procedures.

**Key Words** • wrong-site surgery • “time-out” process • spinal localization • medical malpractice • complication

**Preoperative Verification of Surgery**

An important strategy to prevent WSS involves using a preoperative checklist of procedures and points of discussion designed to ensure that the intended operation is being performed on the correct patient. Both the NASS and the Joint Commission have developed guidelines designed to foster communication among the surgical team, anesthesiologist, nursing staff, and the patient. Both organizations suggest that all members of the clinical staff, as well as the patient, should be involved in marking the site of surgery. Involvement of the patient helps to ensure that everyone understands the surgery to be performed, and it allows the clinical team to confirm that the intended surgery coincides with the patient's symptomatology (that is, a left-sided discectomy for left-sided radicular pain). The Joint Commission guidelines further recommend that a formal “time-out” process be performed immediately before making incision. The time-out procedure should include discussion of the patient's identity, site of surgery, and procedure to be performed. Intraoperative localization of the exact spinal levels of interest is suggested, but not mandated by either set of guidelines.

It is important to acknowledge that even a strict adherence to guidelines proposed by the Joint Commission or NASS will not prevent all instances of WSS during spinal procedures. In a review of 13 nonspine WSSs identified in a health insurance administrative database, Kwaan...
Localization in the Cervical Spine

Accurate spinal localization can successfully be achieved using a combination of anatomical landmarks, clinical correlation (the presence of fractures, instability, and so on), and intraoperative radiological studies. Although sole dependence on 1 of these 3 strategies usually leads to successful localization, multiple strategies should be used to ensure the prevention of WSS. Anatomical landmarks are easily identifiable in the cervical spine of most patients. The large C-2 spinous process can be used for localization in the upper cervical spine, whereas T-1 (with a large lamina and transverse process that articulates with the first rib laterally, a significant contrast compared with the small lateral mass of C-7 that does not articulate with a rib) can be used to localize levels in the lower cervical spine.

For the majority of patients with normal body habitus, plain radiographs or fluoroscopy provide adequate resolution for localization in the cervical spine. For patients with a large body habitus or short neck, visualization of the lower cervical spine can be challenging. Even with caudal traction of the shoulders performed using tape, it may be impossible to obtain adequate imaging of the lower cervical spine. This challenge is typically surmounted by affixing an instrument into a fixed structure in the upper cervical spine that can be visualized radiographically and “counting downward” to deduce the level of interest. This technique typically yields satisfactory results but may require unneeded exposure of the upper cervical spine.

One anomaly of the cervical spine that can potentially lead to WSS is a fused spinal level in a patient with Klippel-Feil syndrome, defined as congenital fusion of any 2 cervical vertebrae. A particularly confusing scenario involves patients with fusion of the C-2 and C-3 vertebrae (Fig. 1). In such a situation, the C-3 vertebrae can easily be mistaken for the dens of C-2 on radiographic imaging. Furthermore, the spinous processes of C-2 and C-3 are often fused and difficult to distinguish intraoperatively, thereby further increasing the risk of WSS. Early recognition and due diligence intraoperatively can prevent an unsatisfactory outcome in such a situation.

Localization in the Thoracic Spine

As with localization in the cervical spine, plain radiographs or fluoroscopy usually provide adequate resolution for localization in the thoracic spine. In some individuals, a combination of such factors as a patient’s size, scapular shadows, and decreased bone density (for example, patients with osteoporosis) makes accurate intraoperative visualization of the bone anatomy difficult with standard radiographs or fluoroscopy. Even in a best-case scenario, when the patient is thin with normal bone density, care must be taken when localizing lesions in the midthoracic spine. When using plain radiographs, it is not uncommon to require multiple studies, with a marker (e.g., spinal needle) placed at a fixed point on the spine to count from C-2 or the sacrum to the level of interest (Fig. 2). If the practitioner is not careful, incorrect identification of a spinal level is a potential hazard. Real-time fluoroscopic imaging is another localization option, but care must be taken to limit radiation exposure to both the patient and the clinical staff.

When using radiographs or fluoroscopy for midthoracic to low thoracic spine localization, it is often easier to count up from the sacrum to the level of interest instead of caudally from the occiput. The surgeon must keep in mind that the level of the lesion may be described by the radiologist by counting from the occiput downward. In rare situations in which there are 4 or 6 lumbar vertebrae, counting from the sacrum upward would lead to localization at the wrong level (Fig. 3). To prevent such an occur-

Intraoperative Localization

Accurate and efficient intraoperative localization of spinal lesions is critical to patient safety and maximizing clinical outcomes. This task is especially challenging in certain clinical situations, including operations in morbidly obese patients, those with pathological entities in the thoracic spine, and patients with variations in spinal anatomy. Failure to anticipate such issues preoperatively can lead to prolonged localization time during the operation or to WSS. The following discussion highlights common pitfalls in spinal localization and reviews current techniques that can be used to expedite spinal localization and prevent WSS.

Localization of C2–3 VBs and spinous processes.
Strategies to avoid wrong-site surgery during spinal procedures

Preoperative imaging should include both the level of interest and the entire lumbar spine when a surgeon anticipates the need to count from the sacrum upward. In addition, the surgeon should use the same counting technique (either rostral or caudal) on both preoperative and intraoperative imaging to avoid this complication.

To expedite localization in the thoracic spine, there are a number of strategies that have been described that may potentially help to avoid WSS. For example, radiopaque skin markers can be placed prior to an MR imaging study or CT scan to localize spinal lesions intraoperatively. This technique may be subject to significant localization error, because the skin and underlying subcutaneous tissues of patients may undergo dramatic shifting and/or folding during positioning. Resulting errors in localization can be dramatic, particularly in obese patients.

In patients undergoing operative procedures in the high thoracic spine, the use of methylene blue dye has been described to mark the spinous process of interest. An anteroposterior radiograph is used to localize the spinous process preoperatively by visualizing dye injected with a 22-gauge needle into the tissue surrounding the relevant spinous process. Although potentially useful for posterior approaches to the thoracic spine, it is not feasible for anterior surgical techniques. In addition, because this dye may be neurotoxic, it must be administered superficially over the posterior spinal elements to avoid inadvertent injection into the spinal canal. Unfortunately, such superficial placement may fail to localize the level with sufficient specificity, because the dye may spread over more than 1 spinous process before surgical exposure can be accomplished.

A novel fluoroscopic technique for thoracic spine localization has recently been described. Instead of depending on true lateral fluoroscopic images that may be inadequate for visualization of the cervicothoracic junction in patients with large body habitus, the fluoroscope is rotated so that the lamina is visualized en face. The resulting oblique fluoroscopic view avoids much of the chest and shoulder mass, thus resulting in a clearer image. Patients undergoing a procedure in which they are placed prone are ideally situated for such a technique. However, in patients with osteoporosis or those undergoing procedures in a lateral decubitus position (that is, thoracotomy), this technique may not be sufficient.

Preoperative vertebroplasty has been used for thoracic spine localization. Unlike the techniques outlined above, this procedure can be used during anterior approaches to the thoracic spine. For this procedure, PMMA impregnated with barium sulfate is clearly visible on radiographs or fluoroscopic studies, thus facilitating the planning of the initial incision and verifying the correct thoracic level of interest intraoperatively (Fig. 4). Injection of PMMA into a VB under fluoroscopy is generally a safe procedure. However, reported complications include radiculopathy, infection, pulmonary fat emboli, pulmonary cement emboli, anaphylaxis, pneumothorax, and epidural extrusion with spinal cord compression. However, the overall risk of serious complications from this procedure is low. Cheris et al. reported a complication rate of 1.3% in osteoporotic compression fractures treated with vertebroplasty, but noted higher complication rates in more destructive bone lesions such as hemangiomas (2.5%) and vertebral malignancies (10%). Because the use of vertebroplasty for spine localization involves the injection of only small amounts of PMMA into a relatively normal VB, it is unclear if this technique harbors the same level of risk compared with vertebroplasty for the treatment of vertebral lesions.

Radiopaque coils have been described for the purpose of thoracic spine localization. Using biplanar fluoroscopy, detachable coils are deposited through a needle adjacent to the pedicle of interest. These coils are easily visualized using standard radiographic techniques. Although this pro-

Fig. 2. Localization of the T-10 VB on serial radiographs. Left: Initial radiograph clearly visualizing the sacrum, demonstrating that a spinal needle is directed at the L-3 pedicle. Right: A second radiograph visualizing the same spinal needle seen in the first study, as well as a clamp affixed to the T-10 lamina.

Fig. 3. Left: Sagittal T2-weighted MR imaging study demonstrating a lesion involving a VB. When counting caudally from C-2, the entity was described as a T-7 lesion. Right: Sagittal CT scan obtained in the same patient demonstrating that when counting cephalad from the sacrum, the same lesion would be described as involving the T-8 VB.
Procedure carries the potential risk of infection, this technique does not carry the risks associated with vertebroplasty and does not disturb the VB of interest.

Localization in the Lumbar Spine

The localization of spinal lesions is generally straightforward in the lumbar spine, but rare instances of WSS in this location can occur without appropriate due diligence. It is critical that, when appropriate, the side of surgery is explicitly verified by the patient, surgeon, and clinical staff before the patient is intubated. Such a process adds another safeguard to prevent WSS, particularly in patients suffering from radicular pain caused by a disc herniation. The patient’s preoperative imaging should be available in the operating room for verification that the correct level is being addressed, and these studies can be compared with any images obtained intraoperatively.

There are multiple strategies that can be used to localize the correct level in the lumbar spine. The placement of a clamp on a spinous process or a curette under a lamina followed by a lateral radiograph are commonly used techniques, but these strategies may occasionally lead to unnecessary confusion during the interpretation of the resultant radiograph. We prefer placing a clamp on the transverse process (which is always lateral to the lumbar pedicle) before taking a lateral radiograph. The resulting radiograph always clearly shows a marker adjacent to a pedicle. The levels of interest can then be surmised based on this radiograph.

The use of a spinal needle or other marking method in conjunction with radiographic imaging to plan the initial incision is a common practice in lumbar spine surgery, particularly in cases in which only a small skin incision is necessary to provide lumbar spine exposure appropriate for the procedure of interest (such as lumbar discectomy) (Fig. 5A). In the vast majority of cases, this technique can be used to localize the level of interest accurately. However, it would be a mistake to depend only on this image for the purposes of spinal imaging. For lumbar discectomy, exposure of the wrong lumbar level before commencement of discectomy is a common occurrence, and failure to obtain further imaging intraoperatively before proceeding with the discectomy may potentially increase the risk of WSS. To prevent WSS during lumbar spine discectomy surgery, we routinely obtain 2 radiographic images in addition to any images obtained before skin in-
Prevention of WSS Using 3D Intraoperative Imaging

Intraoperative 3D imaging is used by many spine surgeons during routine and complex spinal surgery. The vast majority of the literature on this subject focuses on improving the accuracy of instrumentation placement relative to freehand or 2D fluoroscopic techniques. One advantage of 3D intraoperative imaging that is not often discussed is the accurate localization of the correct spinal level of interest. Real-time 3D imaging may be particularly useful during repeat lumbar spine surgery. Patients with a prior fusion surgery in whom a large bony fusion mass develops may lack classic anatomical landmarks, which can make spinal localization difficult. Although we do not advocate the use of 3D imaging techniques for the sake of localization alone, this modality should be considered if the surgeon anticipates difficulty with intraoperative localization.

Conclusions

Wrong-site surgery is a rare complication that can lead to significant clinical morbidity, increased healthcare costs, and medical-legal consequences. This should be viewed as a preventable complication, and verification of the intended site of surgery preoperatively is critical; standardized checklists can help facilitate this process. Recognition of the unique challenges in spinal localization should be acknowledged, and there are many strategies that are safe and easy to implement that can help to ensure accurate intraoperative localization.

Disclosure

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Author contributions to the study and manuscript preparation include the following: Acquisition of data: Hsu. Drafting the article: Hsu. Critically revising the article: Kretzer, Dorsi. Study supervision: Gokaslan.

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